



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

|  |           |  |
|--|-----------|--|
| <b>(51) International Patent Classification <sup>5</sup> :</b><br>G01N 33/53, 33/577, 33/82<br>C07K 15/28  | <b>A1</b> | <b>(11) International Publication Number:</b> WO 91/00519<br><b>(43) International Publication Date:</b> 10 January 1991 (10.01.91)  |
| <b>(21) International Application Number:</b> PCT/US90/03416<br><b>(22) International Filing Date:</b> 15 June 1990 (15.06.90)<br><br><b>(30) Priority data:</b><br>371.234                      26 June 1989 (26.06.89)                      US<br><br><b>(71) Applicant:</b> TRITON BIOSCIENCES, INC. [US/US];<br>1501 Harbor Bay Parkway, Alameda, CA 94501 (US).<br><br><b>(72) Inventors:</b> POURFARZANEH, Mohammed, T. ; 37 Shannon Circle, Alameda, CA 94501 (US). KATSILOMETES, George, W. ; 16 Durango Court, Sacramento, CA 95833 (US).<br><br><b>(74) Agent:</b> SCHUURMAN, Willem, G.; Arnold, White & Durkce, P.O. Box 4433, Houston, TX 77210 (US). |           | <b>(81) Designated States:</b> AT (European patent), BE (European patent), CA, CH (European patent), DE (European patent)*, DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent).<br><br><b>Published</b><br>- - <i>With international search report.</i><br><i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> |
| <b>(54) Title:</b> VITAMIN B <sub>12</sub> ASSAY<br><br><b>(57) Abstract</b><br><br>Immunoassays for vitamin B <sub>12</sub> using novel monoclonal antibodies to the intrinsic factor: vitamin B <sub>12</sub> complex and to the vitamin B <sub>12</sub> binding site on intrinsic factor.   |           |  |

5

10

15

20

25

30

35

of (

comj

porj

and

to l

dim

the

the

gro

deo

iso

Hyd

deo

coe

cob

are

gro

and

prc

int

gly

abs

mol

mar

# DESIGNATIONS OF "DE"

Until further notice, any designation of "DE" in any international application whose international filing date is prior to October 3, 1990, shall have effect in the territory of the Federal Republic of Germany with the exception of the territory of the former German Democratic Republic.

## FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

|    |                              |    |                                       |    |                          |
|----|------------------------------|----|---------------------------------------|----|--------------------------|
| AT | Austria                      | ES | Spain                                 | MC | Monaco                   |
| AU | Australia                    | FI | Finland                               | MG | Madagascar               |
| BB | Barbados                     | FR | France                                | ML | Mali                     |
| BE | Belgium                      | GA | Gabon                                 | MR | Mauritania               |
| BF | Burkina Faso                 | GB | United Kingdom                        | MW | Malawi                   |
| BG | Bulgaria                     | GR | Greece                                | NL | Netherlands              |
| BJ | Benin                        | HU | Hungary                               | NO | Norway                   |
| BR | Brazil                       | IT | Italy                                 | RO | Romania                  |
| CA | Canada                       | JP | Japan                                 | SD | Sudan                    |
| CF | Central African Republic     | KP | Democratic People's Republic of Korea | SE | Sweden                   |
| CG | Congo                        | KR | Republic of Korea                     | SN | Senegal                  |
| CH | Switzerland                  | LI | Liechtenstein                         | SU | Soviet Union             |
| CM | Cameroon                     | LK | Sri Lanka                             | TD | Chad                     |
| DE | Germany, Federal Republic of | LU | Luxembourg                            | TC | Togo                     |
| DK | Denmark                      |    |                                       | US | United States of America |

5

VITAMIN B<sub>12</sub> ASSAY

10

Vitamin B<sub>12</sub> (cyanocobalamin) has an empirical formula of C<sub>63</sub>H<sub>88</sub>O<sub>14</sub>N<sub>14</sub>PCo (Mol. Wt. 1355.4 daltons) and is a complex molecule having three major components: a porphyrin-like ring structure consisting of four reduced and extensively substituted pyrrole rings (designated A to D) surrounding a single cobalt atom; an α-5,6--dimethylbenzimidazole ribonucleotide group which links to the corrin nucleus with bonds to the cobalt atom and to the propionate side chain of the D ring; and a variable R group which can be cyanide, hydroxyl, methyl or 5-deoxyadenosyl. The cyano-substitution is an artifact of isolation but is the form which is currently assayed. Hydroxycobalamin, methylcobalamin and 5-deoxyadenosylcobalamin are the physiologically active coenzyme forms of vitamin B<sub>12</sub>. The two major active cobalamins, methylcobalamin and 5-deoxyadenosylcobalamin, are essential for DNA biosynthesis, replication and cell growth.

10

15

Dietary vitamin B<sub>12</sub>, in the presence of gastric acids and pancreatic proteases, is released from intestinal R protein-like binding proteins and is immediately bound to intrinsic factor (IF), the gastrointestinal binding glycoprotein responsible for the specific binding and absorption of vitamin B<sub>12</sub>. Intrinsic factor has a molecular weight of approximately 40,000 and differs markedly in structure from the R proteins. Its ability

- 2 -

to bind vitamin B<sub>12</sub> at the exclusion of metabolically inactive cobinamide has led to the predominant use of this binding protein in the commercially available vitamin B<sub>12</sub> assays. The IF:vitamin B<sub>12</sub> complex interacts with the ileal mucosal cells and is then absorbed into the blood stream.

Following absorption, all three active cobalamins are present in plasma bound to plasma-binding proteins known as transcobalamin-II and R proteins (also known as nonintrinsic factors). Transcobalamin II binds approximately 20% of the total plasma vitamin B<sub>12</sub> while the remainder is bound to the R proteins. Vitamin B<sub>12</sub> bound to transcobalamin II, is rapidly cleared from the plasma and delivered to a variety of cells, such as the hepatic parenchymal cells of the liver. The R proteins may also play a role in the delayed transport and cellular delivery of vitamin B<sub>12</sub> to the liver. Because of the high affinity with which the plasma-binding proteins bind vitamin B<sub>12</sub>, the denaturation of these proteins is necessary in the performance of cyanocobalamin assays.

Vitamin B<sub>12</sub> deficiency is due primarily to a disruption of IF:vitamin B<sub>12</sub> binding resulting from a failure of parietal cell production of intrinsic factor or the production of anti-intrinsic factor antibodies. The failure of parietal cells is probably due to the presence of cytotoxic autoantibodies. Serum antibodies to intrinsic factor have been extensively studied. Two types of antibodies have been identified: the blocking antibody (Type I), which blocks the binding of vitamin B<sub>12</sub> to IF and a nonblocking antibody (Type II), which reacts with the IF:vitamin B<sub>12</sub> complex. Serum blocking antibodies are present in 50-76% of vitamin B<sub>12</sub> deficient patients and have a high degree of specificity for the diagnosis of pernicious anemia. Commercial assay kits which measure the levels of these anti-IF antibodies are

avai  
util  
vita

defe  
def:  
leac  
of  
sec  
par  
mal  
vit  
(ve  
and

sta  
del  
mos  
aff  
ser  
cli  
dev  
as  
the  
the  
dia

as:  
Mi  
mi  
le  
re  
am  
sa

available (Corning ImmoPhase IFAB) and studies on the utility of these assays in the differential diagnosis of vitamin B<sub>12</sub> deficiency have proceeded to the present.

5 Vitamin B<sub>12</sub> deficiency is more commonly caused by defective gastrointestinal absorption than from a deficient diet. Therefore, additional factors which can lead to vitamin B<sub>12</sub> malabsorption include the combination of gastric achlorhydria and decreased secretion of IF  
10 secondary to gastric atrophy or surgery, intestinal parasites, bacterial gastroenteritis and intestinal malignancies. Other disorders which may account for a vitamin B<sub>12</sub> deficiency include dietary deprivation (veganism), drugs, organ disease (liver), hyperthyroidism  
15 and transcobalamin II aberrations.

A deficiency in vitamin B<sub>12</sub> can lead to disease states marked by defective DNA synthesis culminating in  
f delayed cellular mitosis. Since the cells having the most rapid metabolism will be the most dramatically  
20 affected, the hematopoietic system is particularly sensitive to vitamin B<sub>12</sub> deficiencies. The primary clinical manifestation of this vitamin deficiency is the development of a megaloblastic anemia which is also known  
15 as pernicious anemia. Vitamin B<sub>12</sub> is also implicated in the maintenance of the myelin of the nervous system. For these reasons, it is very important to be able to diagnose vitamin B<sub>12</sub> deficiencies.

10 The current state of the art regarding vitamin B<sub>12</sub> assays utilizes a wide variety of assay techniques. Microbial assays are based upon the principle that some microorganisms such as Euglena gracilis and Lactobacillus leichmannii require vitamin B<sub>12</sub> for normal growth and  
15 replication. Standard curves are produced using known amounts of vitamin B<sub>12</sub> and bacterial growth produced by a sample containing an unknown amount of vitamin B<sub>12</sub> is

- 4 -

compared with the standard curve. Bacterial growth can be measured in numerous ways but the most common is turbidimetric measurement.

5           The deoxyuridine suppression test is performed on bone marrow cells which have been aspirated from the patient. A vitamin B<sub>12</sub> deficiency is noted if there is a reduction in the suppression of radioactive iododeoxyuridine incorporation into DNA by deoxyuridine.

10           High-performance liquid chromatography is based upon the variability in the rate of travel of different compounds through a medium under pressure within a column. The elutes are then detected at picogram/ml concentrations by ultra-violet or other detectors such as fluorescence and electrochemical detection.

15           Another method involves the use of antisera specific to vitamin B<sub>12</sub> which are employed in specific radioimmunoassays to directly measure the liberated vitamin.

20           Still another method involves competitive protein-binding radioimmunoassays (radioisotopic dilution assays). These assays have the prerequisite that the vitamin B<sub>12</sub> in the sample be freed from its binding proteins by physical, chemical or enzymatic denaturation or digestion. The most commonly used methods are the boil method which involves boiling the sample for 15-30 minutes and the non-boil method which involves the use of highly alkaline buffer solutions containing KCN which simultaneously denature the binding proteins and convert the cobalamins to the stable cyanocobalamin form. Both the boil and the non-boil methods use radioactive (<sup>57</sup>Co-labelled) vitamin B<sub>12</sub> in a competitive system which employs purified hog intrinsic factor as the binding

ac  
vi5    B<sub>1</sub>  
ne  
st  
st  
er  
10 us  
Fu  
in  
pa  
gr  
15 B<sub>1</sub>  
tc  
mc  
ac  
as  
20 adpr  
cc  
25 be  
kitc  
30 sp  
ir  
mc  
si  
di  
35 ar

agent and a separation step to remove unbound sample vitamin B<sub>12</sub>.

5 In spite of the fact that there are numerous vitamin B<sub>12</sub> assays currently available, there remains a continuing need for an improved assay that will overcome the shortcomings of the state of the art techniques. These shortcomings include a lack of sensitivity, difficulties encountered in standardization and the impracticality of use in high volume situations, i.e. in hospitals. 10 Further, there are no commercial non-isotopic immunoassays for this analyte on the market. During the past decade, major attempts have been made by numerous groups to produce such a non-isotopic test for vitamin B<sub>12</sub>. These attempts have been unsuccessful, due primarily 15 to the small size and complexity of the vitamin B<sub>12</sub> molecule. Therefore, there is a current need for an accurate, precise and reliable reference method for assaying cyanocobalamin. This invention is intended to address that need. 20

This invention pertains to the development of a process and an immunoassay for the determination of the concentration of vitamin B<sub>12</sub> in a sample. The process can 25 be performed manually such as by means of a diagnostic kit or automatically such as in an automatic analyzer.

10 In particular, this invention in one aspect pertains to the production and isolation of monoclonal antibodies specific to the intrinsic factor: vitamin B<sub>12</sub> complex and in another aspect to the production and isolation of monoclonal antibodies specific to the vitamin B<sub>12</sub> binding site on intrinsic factor. Further, this invention is directed at the production and isolation of monoclonal 15 antibody lines capable of producing these antibodies.

- 6 -

Figure 1 is a titer curve for several monoclonal antibody cell lines, depicting the percentage of  $^{125}\text{I}$ -IF bound versus the amount of antibody dilution.

5        Figure 2 is a bar graph illustrating the effect of different monoclonal antibodies on vitamin  $\text{B}_{12}$  binding to intrinsic factor.

10       Figure 3 is a calibration curve illustrating the specificity of the monoclonal antibodies of this invention for the vitamin  $\text{B}_{12}$  binding site on IF.

15       This invention provides for the development of a process and an immunoassay for determination of the concentration of vitamin  $\text{B}_{12}$  in serum or other body fluids which involves the use of novel monoclonal antibodies. The preferred embodiment of this invention pertains to the production of monoclonal antibodies specific to the vitamin  $\text{B}_{12}$  binding site on intrinsic factor. In a competitive assay, vitamin  $\text{B}_{12}$  would compete with labelled monoclonal antibodies for binding to intrinsic factor. Use of these site-specific antibodies in such an assay, enables indirect measurement of vitamin  $\text{B}_{12}$ , as the vitamin  $\text{B}^{12}$  levels are measured by monitoring antibody binding to IF. The amount of antibody bound is inversely proportional to the amount of vitamin  $\text{B}_{12}$  present. The sample is first boiled or pretreated with a denaturing solution (non-boil method) to release vitamin  $\text{B}^{12}$  from its binding proteins, to which it is strongly bound. 20       Following denaturation, the "site specific" monoclonal antibody reagent and labelled intrinsic factor are added and incubated with the sample.

35       Another embodiment of the invention pertains to the production of monoclonal antibodies specific to the IF: vitamin  $\text{B}_{12}$  complex and use of these antibodies to identify the IF: vitamin  $\text{B}_{12}$  complex. Sample preparation

is  
Bi  
la  
ar  
5     $\text{B}_{12}$   
me  
pr

10    an  
usu  
mo  
(b  
is  
15    al  
lat  
lat  
whi  
en  
20    way  
Lat  
met  
inc

25    is  
oth  
lig  
can  
30    ant  
Pre  
col  
or  
lim  
35    mal  
per



is identical to that for the embodiment described above. Binding of the sample vitamin B<sub>12</sub> is accomplished by labelled IF. The antibodies to the IF:vitamin B<sub>12</sub> complex are labelled for use in identification of the IF:vitamin B<sub>12</sub> complex and separation is accomplished by standard methods. Monoclonal antibody binding is in direct proportion to the amount of sample vitamin B<sub>12</sub> present.

Labelling of intrinsic factor and the monoclonal antibodies can be done by incorporating labels commonly used in state of the art immunoassays, such as hapten molecules, radioactive atoms or groups, enzymes, vitamins (biotin), dyestuff or fluorescent groups. This labelling is usually performed before any immunological reaction is allowed to take place. However, it may be performed at a later stage by allowing the component which must be labelled to react with the corresponding binding partner, which has previously been labelled. The coupling of the enzyme/dyestuff/fluorogen can be brought about in a known way, for example by the formation of an amide linkage. Labelling with a radioisotope can also be performed by methods well established in the art. Useful isotopes include, without limitation, <sup>125</sup>I, <sup>131</sup>I, <sup>14</sup>C and <sup>3</sup>H.

In the preferred embodiment, one of the labels used is a signal generating label for use in detection and the other label is capable of being captured by a capture ligand on a solid phase. For example, intrinsic factor can be labelled with an enzyme and the monoclonal antibodies labelled with a hapten, or vice versa. Preferably, the enzymes are those which can be colorimetrically, electrochemically, spectrophotometrically or fluorometrically determined. These include, without limitation, alkaline phosphatase, acetylcholinesterase, malate dehydrogenase, egg white lysozyme, horseradish peroxidase and  $\beta$ -galactosidase. The preferred hapten

- 8 -

molecule is a fluorogenic molecule, for example fluorescein isothiocyanate (FITC).

5 The preferred solid phase is magnetizable particles, but this invention also contemplates the use of filter paper, plastic beads, or test tubes made from polyethylene, polystyrene, polypropylene or other suitable materials. Also useful are particulate materials such as agarose, crosslinked dextran, and other polysaccharides. Techniques for binding to the solid phase are also well known in the art. Numerous solid support materials and binding methods can be used, examples of which are described in U.S. Patent No. 4,659,678, incorporated herein by reference.

15 Separation of the complexes may be by any of a variety of physical, chemical or immunological techniques. Likewise, any of the common substrates known in the immunoassay art may be used. The preferred separation procedure uses antibodies linked to magnetizable particles. Examples include the fluorescein antibody magnetizable particle (FAMP) method as described in S.J. Rattle et al., Clin. Chem. 30(9):1457-1461 (1984) or double antibody magnetic particle separation, using anti-mouse labelled magnetic particles as described in U.S. Patent No. 4,659,678. Another suitable separation procedure is the covalently linked antibody magnetic particle separation method, which involves mixing the antigen-containing sample with two monoclonal antibodies raised against different epitopes of the antigen, where one monoclonal antibody is enzyme labelled and the other is covalently bound to a polyclonal antibody raised against FITC, which is subsequently covalently bound to magnetizable particles. Other separation procedures may also be suitable.

b  
a  
tlin  
in  
er  
3:  
St  
Sc  
de  
ccar  
tr

vi

mc  
si  
tc  
fa

fc

ar

cc  
vi

In both embodiments of the present invention, it may be necessary to utilize labelled antibodies specific for alternate determinant sites on IF in order to identify the (IF:vitamin B<sub>12</sub>)(monoclonal antibody) complex.

5 It is possible to amplify the sensitivity of immunoassays using monoclonal antibodies of this invention in numerous fashions. Typical examples are enzyme amplification, Stanley et al., Am Biotechnol. Lab. 3:48-53 (1985), and the biotin-avidin method, L.A. Sternberger, Immunocytochemistry, 2nd ed., John Wiley & Sons (1979). These designs will theoretically yield the desired sensitivity because the primary reagents are combined in solution prior to separation.

15 The vitamin B<sub>12</sub> immunoassay utilizing monoclonal antibodies to the vitamin B<sub>12</sub> binding site on IF involves the following steps:

20 treating a sample of the fluid to free vitamin B<sub>12</sub> from the binding proteins;

25 contacting the sample with labelled monoclonal antibodies specific to the vitamin B<sub>12</sub> binding site on intrinsic factor and labelled intrinsic factor, to form intrinsic factor:antibody and intrinsic factor:vitamin B<sub>12</sub> complexes;

30 adding a solid phase to said complexes to form bound and unbound complexes;

35 separating the bound and unbound complexes and washing; and

40 measuring either the amount of bound complex or unbound complex to quantify the amount of vitamin B<sub>12</sub> present in the sample. If the amount of

- 10 -

intrinsic factor:antibody is measured, the value will be inversely proportional to the amount of vitamin B<sub>12</sub> present in the sample. If the intrinsic factor:vitamin B<sub>12</sub> is measured, the value is directly proportional.

5

Accordingly, an immunoassay of this embodiment of the invention would comprise (1) monoclonal antibodies that bind to the vitamin B<sub>12</sub> binding site on intrinsic factor and block the binding of vitamin B<sub>12</sub> to intrinsic factor said monoclonal antibodies being labelled with a first label, (2) intrinsic factor labelled with a second label and (3) a solid phase containing a capture ligand for one of said labels with the other label being a signal generating label for use in detection. The process itself is illustrated in Example 1. For purposes of illustration only, the monoclonal antibodies are labelled with FITC, intrinsic factor is enzyme labelled. Separation is done by the FAMP method, so magnetizable particles are used as the solid phase with antibodies specific to FITC being the capture ligand. These steps are not intended to limit the invention in any manner but are merely illustrative of an assay that can be developed using these novel monoclonal antibodies.

25

## EXAMPLE 1

1. The sample containing the vitamin B<sub>12</sub> (B<sub>12</sub>) analyte bound to the binding proteins, is chemically or physically (e.g. heat or change in pH) pretreated. This pretreatment frees the analyte, resulting in a sample containing free vitamin B<sub>12</sub> and the denatured binding proteins.
2. The sample is mixed with FITC conjugated monoclonal antibodies (FITC-MAb) which are specific to the IF binding site and subsequently incubated with enzyme labelled

35

- 11 -

intrinsic factor (IF-EZ). This is a competitive step since the vitamin B<sub>12</sub> "competes" with the monoclonal antibodies for binding to IF.

5 B<sub>12</sub> + FITC-MAb + IF-EZ      EZ-IF:MAb-FITC + EZ-IF-B<sub>12</sub>

3. Antibodies specific to the label used on the monoclonal antibodies; in this instance FITC (α-FITC), coupled to magnetizable particles (MP) are added in excess.

10

MP-α-FITC + EZ-IF:MAb-FITC      MP-α-FITC:FITC-MAb:IF-EZ

4. The captured complexes are then separated by magnetic particle separation and washed to remove the free IF-EZ.

15

5. The signal from the MP-bound complex is then measured spectrophotometrically following the addition of a substrate reagent such as pNPP and/or an amplification reagent. The color intensity obtained is inversely proportional to the vitamin B<sub>12</sub> concentration.

20

15 The vitamin B<sub>12</sub> immunoassay utilizing monoclonal antibodies to the IF:vitamin B<sub>12</sub> complex involves the following steps:

treating a sample of the fluid to free vitamin B<sub>12</sub> from the binding proteins;

0

contacting the sample with labelled intrinsic factor, in excess, and labelled monoclonal antibodies specific to the intrinsic factor:vitamin B<sub>12</sub> complex, in excess, to form intrinsic factor:vitamin B<sub>12</sub>:antibody complexes;

5

- 12 -

adding a solid phase to said complexes to  
form bound and unbound complexes;

5 separating the bound and unbound complexes  
and washing; and

measuring either the amount of bound  
complex or unbound complex to quantify the amount of  
vitamin B<sub>12</sub> present in the sample. If the amount of  
10 intrinsic factor:vitamin B<sub>12</sub>:monoclonal antibody is  
measured, the value will be directly proportional to the  
amount of vitamin B<sub>12</sub> in the sample. If the amount of  
excess monoclonal antibodies is measured, the value will  
be inversely proportional.

15 Accordingly, an immunoassay of this embodiment of  
the invention would comprise (1) monoclonal antibodies  
that bind to the intrinsic factor:vitamin B<sub>12</sub> complex said  
monoclonal antibodies being labelled with a first label,  
20 (2) intrinsic factor labelled with a second label and (3)  
a solid phase containing a capture ligand for one of said  
labels with the other label being a signal generating  
label for use in detection. The process itself is  
illustrated in Example 2. The intrinsic factor is  
25 labelled with FITC and the monoclonal antibodies are  
enzyme labelled. Separation is by the FAMP method. Once  
again, these parameters are merely illustrative and are  
not intended to limit the invention in any manner.

30 EXAMPLE 2

1. The sample, containing the vitamin B<sub>12</sub> (B<sub>12</sub>)  
analyte bound to the binding proteins, is  
chemically or physically (e.g. heat or change  
35 in pH) pretreated. This pretreatment frees the  
analyte, resulting in a sample containing  
vitamin B<sub>12</sub> and free denatured binding proteins.

th  
in  
pr

- 13 -

2. The sample is then mixed and subsequently incubated with an excess of FITC conjugated intrinsic factor (FITC-IF) together with an excess of enzyme labelled monoclonal antibodies (EZ-MAb) which recognize the IF: vitamin B<sub>12</sub> complex.

10 B<sub>12</sub> + FITC-IF + EZ-MAb      EZ-MAb  
FITC-IF: B<sub>12</sub> + FITC-IF + EZ-MAb

3. Antibodies specific to the label used on intrinsic factor, in this instance FITC ( $\alpha$ -FITC), coupled to magnetizable particles (MP) are added to the sample in excess to separate the complexes.

20 MP- $\alpha$ -FITC + FITC-IF: B<sub>12</sub> + FITC-IF + EZ-MAb

MP- $\alpha$ -FITC: FITC-IF: B<sub>12</sub> + MP- $\alpha$ -FITC: FITC-IF + EZ-MAb

4. The captured complexes are then separated by magnetic particle separation and washed to remove the free EZ-MAb.

5. The signal from the labelled monoclonal antibodies in the bound complex is then measured spectrophotometrically following the addition of a substrate reagent such as pNPP and/or an amplification reagent. The color intensity obtained is directly proportional to the vitamin B<sub>12</sub> concentration.

The method of obtaining the monoclonal antibodies of this invention is that discussed by Kohler and Milstein in Nature 256:495-497 (1975). Summarized briefly, this process involves injecting an animal with an immunogen

- 14 -

(Example 3 and 4). The animal is then sacrificed and cells taken from its spleen, which are then fused with myeloma cells. The result is a hybrid cell or "hybridoma" that is capable of reproducing in vitro. The population of hybridomas is then screened to isolate individual clones, each of which secrete a single antibody species to the immunogen (Example 5). In this manner, the individual antibody species obtained, are the product of a single B cell from the immune animal generated in response to a specific site recognized on the immunogenic substance. This method is best described with reference to the following examples, which are merely illustrative of the present invention and should not be considered as limiting the scope of the invention in any manner.

Preparation of the IF:vitamin B<sub>12</sub> complex is accomplished by mixing commercially available highly purified hog intrinsic factor with an excess of vitamin B<sub>12</sub>, to insure maximum complex formation. The free vitamin B<sub>12</sub> is then separated by standard gel filtration techniques or dialysis and the IF:vitamin B<sub>12</sub> complex can then be used as the immunogen to produce monoclonal antibodies to the complex.

## EXAMPLE 3

The IF:vitamin B<sub>12</sub> complex immunogen was prepared using a calculated 1:1 molar ratio of IF to vitamin B<sub>12</sub> (1 mg IF binds 30 µg vitamin B<sub>12</sub>). Eight hundred eighty micrograms of IF (16 nM) was combined with 26.4 µg of vitamin B<sub>12</sub> (19.48 nM) in 0.1 M NaH<sub>2</sub>PO<sub>4</sub> (pH 7.5). The calculated molar ratio of vitamin B<sub>12</sub> to IF was 1.22:1. This combination was brought to 2 ml with monobasic phosphate buffer, covered and refrigerated overnight. The immunogen was then purified by FPLC (Pharmacia). Subsequent UV spectrophotometry on the purified complex

g  
r  
d  
m  
p  
ch  
t  
sc  
f  
o  
o  
H  
a  
a  
r  
io  
f  
(  
a  
i  
t  
t  
a  
e



- 15 -

gave a calculated final molar ratio of 1.2:1 with a 96% recover (850 µg). The purity of the immunogen was also determined using native PAGE electrophoresis and the molecular weight was determined by comparison with protein calibrators using high pressure liquid chromatography (Hewlett Packard 1090M).

Standard techniques can be employed to select clonal hybridoma cell lines producing monoclonal antibodies to the IF:vitamin B<sub>12</sub> complex and to the vitamin B<sub>12</sub> binding site on intrinsic factor.

## EXAMPLE 4

Eight mice to be immunized with the IF:vitamin B<sub>12</sub> complex were divided into two groups of four each. The first group received 100 µl of immunogen containing 50 µl of the purified IF:vitamin B<sub>12</sub> complex (27 µg) and 50 µl of Ribi adjuvant (Ribi ImmunoChem Research, Inc., Hamilton, MT). These injections were given by foot pad and by multiple subcutaneous injections in the inguinal and axillary regions. The second group of four mice received 100 µl of the same preparation via multiple intramuscular and intraperitoneal routes.

Six mice were selected and divided into two groups of three each for immunization with purified IF. The first group received 100 µl of immunogen containing 50 µl (25 µg) of IF and 50 µl of Ribi adjuvant/mouse/immunization. These injections were given in the foot pad and subcutaneously at multiple sites in the inguinal and axillary regions. The second group of three received injections of IF at multiple intramuscular and intraperitoneal sites (100 µl total volume).

A schedule of immunizations and bleeds was established to insure a minimum of 3 bouts of exposure.

- 16 -

Prebleeds and test bleeds were evaluated for presence of polyclonal antibodies by screening on antigen coated plates (Costar vinyl).

5           Following the third immunization, the mouse having  
the highest serum binding to IF (mouse B2) and the mouse  
with the highest binding to solid phase IF from the group  
receiving the IF: vitamin B<sub>12</sub> complexes (mouse D4) were  
selected for IV boost and sacrifice. Fusions were  
10       carried out using the principles outlines in Kohler and  
Milstein, Nature 256:495-497 (1975).

Screening techniques were devised to select specific  
hybridoma cell lines capable of producing monoclonal  
15       antibodies to the IF: vitamin B<sub>12</sub> complex and to the  
vitamin B<sub>12</sub> binding site on intrinsic factor.

#### EXAMPLE 5

20           Sera and supernate screening was performed on  
duplicate microtiter plates which had been precoated with  
100 ng/50 µl well of IF in carbonate-bicarbonate buffer  
(50 mM, pH 9.6) and 100 ng/50 µl well of IF: vitamin B<sub>12</sub>  
complex. The plates were incubated at room temperature  
25       for 24-48 hours and were then washed three times and  
blocked with 52 µl of 2% powdered milk in water. The  
plates were then incubated for 1 hour at room temperature  
and were rewashed. Fifty microliters of cell culture  
supernate from each cell line was added to all the wells  
30       and was incubated for 1 hour. The plates were washed and  
50 µl of a 1:10,000 dilution of goat anti-mouse-  
horseradish peroxidase (HRP) conjugate was added and  
incubated for 1 hour. A substrate for HRP (3,3', 5,5'-  
tetramethylbenzidine) was then added and the colored  
35       reaction product was allowed to form for 30 minutes. The  
enzyme-substrate reaction was then stopped by the  
addition of 50 µl of 2 M H<sub>2</sub>SO<sub>4</sub> and the plates were read at

- 17 -

450 nm. This screening procedure permitted selection of several lines which had some degree of specificity for either IF or the IF:vitamin B<sub>12</sub> complex. This procedure, taken with example 8 permitted selection of lines having some degree of specificity for the vitamin B<sub>12</sub> binding site on IF. These cell lines were: 8A4; 6B8; 5G1; 7E4; 2G7; 5E1; 5E11; 1A5; 7H8 and 1G5.

## EXAMPLE 6

Intrinsic factor was labelled with <sup>125</sup>I-Na using the well established chloramine-T method, as set forth in Hunter and Greenwood, Nature (London) 194:495-496 (1962). Intrinsic factor (50 µg in 100 µl distilled water) was mixed with 1 mCi of <sup>125</sup>I-Na (10 µl, Amersham). Chloramine-T (25 µg/25 µl of 0.1 M NaH<sub>2</sub>PO<sub>4</sub> buffer, pH 7.5) was then added and this mixture was incubated for 45 seconds. The reaction was then terminated by the addition of 60 µg (per 50 µl of the phosphate buffer) of sodium metabisulfite. One hundred microliters of the phosphate buffer was then added and the mixture was applied on a PD-10 column (Pharmacia) which had been previously equilibrated with phosphate buffer. The mixture was eluted with the buffer and 0.5 ml fractions were collected in 25 x 75 mm borosilicate tubes. Determination of <sup>125</sup>I activity peaks indicated that fractions 2 and 3 contained 76% of the activity (38 µg/ml).

## EXAMPLE 7

One hundred microliters of cell culture supernate diluted neat, 1:10, 1:100, 1:1000 and 1:5000 were added to duplicate tubes. This was followed immediately by the addition of 100 µl of <sup>125</sup>I-IF tracer (543 pg/tube) which gave the total tube counts of approximately 10,000 cpm. Following a one hour incubation at room temperature, the

- 18 -

bound fraction was separated using sheep anti-mouse magnetic particle (2 mg/100  $\mu$ l) separation. The bound fractions were then counted on a multichannel radioisotope counter (IsoData 20/20). Figure 1 illustrates the titer curves which were obtained employing the supernates from the cell lines selected (1A5, 6B8, 5E11, 8A4, 7E4 and 5G1).

## EXAMPLE 8

10

In order to select antibodies specific for the IF:vitamin B<sub>12</sub> binding site and/or the IF:vitamin B<sub>12</sub> complex, selected supernates were utilized in differential binding studies. Inhibition of <sup>57</sup>Co-labelled vitamin B<sub>12</sub> to intrinsic factor was demonstrated when monoclonal antibody 8A4G11 (expanded clone of the 8A4 cell line) was added in solution with <sup>125</sup>I-IF. This is shown in Figure 2, which also shows how this monoclonal antibody inhibited binding to a significantly greater degree than other monoclonal antibodies. Another study involved the addition of 100  $\mu$ l of 0.1, 1, 10 and 100 ng/ml concentrations of vitamin B<sub>12</sub> (in distilled water); 100  $\mu$ l of the appropriate dilution of monoclonal antibody supernate and 100  $\mu$ l of <sup>125</sup>I-IF (543 pg/tube) to duplicate tubes, followed by incubation for one hour. The bound complex was separated by addition of anti-mouse magnetic particles (2 mg/100  $\mu$ l) after a 15 minute incubation. The calibration curves obtained showed the degree of specificity of monoclonal antibodies for the IF:vitamin B<sub>12</sub> complex. Figure 3 shows the calibration curve for monoclonal antibody 8A4G11 further demonstrating the specificity of this monoclonal antibody for the vitamin B<sub>12</sub> binding the site on IF. The cell line 7H8 also provided monoclonal antibodies specific to the binding site. One other cell line (6B8) also showed displacement of vitamin B<sub>12</sub> which was not as pronounced as that shown by 8A4 and 7H8. The remaining antibodies were either

- 19 -

specific for IF alone (5G1) or were preferentially specific for the IF:vitamin B<sub>12</sub> complex (7E4). The plate and tube screening results led to the initial selection of the following lines for ascites production in pristane primed mice: 8A4, 7H8, 1A5, 6B8, 7E4 and 5G1.

5

CLAIMS:

1. An immunoassay for determining the concentration of vitamin B<sub>12</sub> in a sample comprising monoclonal antibodies that bind to the vitamin B<sub>12</sub> binding site on intrinsic factor and block the binding of vitamin B<sub>12</sub> to intrinsic factor said monoclonal antibodies being labelled with a first label, intrinsic factor labelled with a second label, and a solid phase containing a capture ligand for one of said labels with the other label being a signal generating label for use in detection.
2. Monoclonal antibodies specific for the vitamin B<sub>12</sub> binding site on intrinsic factor and having the ability to block the binding of vitamin B<sub>12</sub> to intrinsic factor.
3. The monoclonal antibodies of claim 2 which are produced by the cell lines 8A4 and 7H8.
4. A complex wherein intrinsic factor having a first label is bound to a monoclonal antibody specific for the vitamin B<sub>12</sub> binding site on intrinsic factor said monoclonal antibody having a second label, where one of said labels is capable of being captured by a capture ligand on a solid phase and the other label is a signal generating label for use in detection.
5. A process for the determination of the concentration of vitamin B<sub>12</sub> in a fluid containing vitamin B<sub>12</sub> bound to binding proteins, comprising the steps of:
  - treating a sample of the fluid to free vitamin B<sub>12</sub> from the binding proteins;
  - contacting the sample with labelled monoclonal antibodies specific to the vitamin B<sub>12</sub> binding site on intrinsic factor and labelled intrinsic

- 21 -

factor, to form intrinsic factor:antibody and  
intrinsic factor:vitamin B<sub>12</sub> complexes;

5 adding a solid phase to said complexes to form bound  
and unbound complexes;

separating the bound and unbound complexes and  
washing; and

10 measuring either the amount of bound complex or  
unbound complex to quantify the amount of  
vitamin B<sub>12</sub> present in the sample.

15 6. The process of claim 5 wherein the monoclonal  
antibodies are labelled with a hapten molecule.

7. The process of claim 6 wherein said hapten molecule  
is fluorescein isothiocyanate.

20 8. The process of claim 5 wherein said intrinsic factor  
is labelled with an enzyme.

25 9. The process of claim 5 wherein in step (e) the  
amount of intrinsic factor:antibody is measured, said  
value being inversely proportional to the amount of  
vitamin B<sub>12</sub> present in the sample.

30 10. The process of claim 5 wherein in step (e) the  
amount of intrinsic factor:vitamin B<sub>12</sub> is measured, said  
value being directly proportional to the amount of  
vitamin B<sub>12</sub> present in the sample.

35 11. The process of claim 5 wherein step (c) involves  
contacting the sample with antibodies specific to the  
label used for the monoclonal antibodies of step (b),  
coupled with magnetizable particles, to form a complex

- 22 -

with the intrinsic factor:antibody complex, and the separation step (d) is by magnetic particle separation.

5 12. An immunoassay for determining the concentration of  
vitamin B<sub>12</sub> in a sample comprising monoclonal antibodies  
that bind to the intrinsic factor:vitamin B<sub>12</sub> complex said  
monoclonal antibodies being labelled with a first label,  
intrinsic factor labelled with a second label, and a  
10 solid phase containing a capture ligand for one of said  
labels with the other label being a signal generating  
label for use in detection.

15 13. Monoclonal antibodies specific for the intrinsic  
factor:vitamin B<sub>12</sub> complex.

14. The monoclonal antibodies of claim 13 which are  
produced by the cell line 7E4.

20 15. A bound complex wherein intrinsic factor having a  
first label is bound to vitamin B<sub>12</sub> forming intrinsic  
factor:vitamin B<sub>12</sub> complex, which is bound to a monoclonal  
antibody specific for the intrinsic factor:vitamin B<sub>12</sub>  
binding site having a second label, where one of said  
labels is capable of being captured by a capture ligand  
25 on a solid phase and the other label is a signal  
generating label for use in detection.

30 16. A process for the determination of the concentration  
of vitamin B<sub>12</sub> in a fluid containing vitamin B<sub>12</sub> bound to  
binding proteins, comprising the steps of:

treating a sample of the fluid to free vitamin B<sub>12</sub>  
from the binding proteins;

35 contacting the sample with labelled intrinsic  
factor, in excess, and labelled monoclonal  
antibodies specific to the intrinsic



- 23 -

factor: vitamin B<sub>12</sub> complex, in excess, to form  
intrinsic factor: vitamin B<sub>12</sub> antibody complexes;

adding a solid phase to said complexes to form bound  
and unbound complexes;

separating the bound and unbound complexes and  
washing; and

measuring either the amount of bound complex or  
unbound complex to quantify the amount of  
vitamin B<sub>12</sub> present in the sample.

17. The process of claim 16 wherein said intrinsic  
factor is labelled with a hapten molecule.

18. The process of claim 17 wherein said hapten molecule  
is fluorescein isothiocyanate.

19. The process of claim 16 wherein the monoclonal  
antibodies are labelled with an enzyme.

20. The process of claim 16 wherein in step (e), the  
amount of intrinsic factor: vitamin B<sub>12</sub> is measured, said  
value being directly proportional to the amount of  
vitamin B<sub>12</sub> present in the sample.

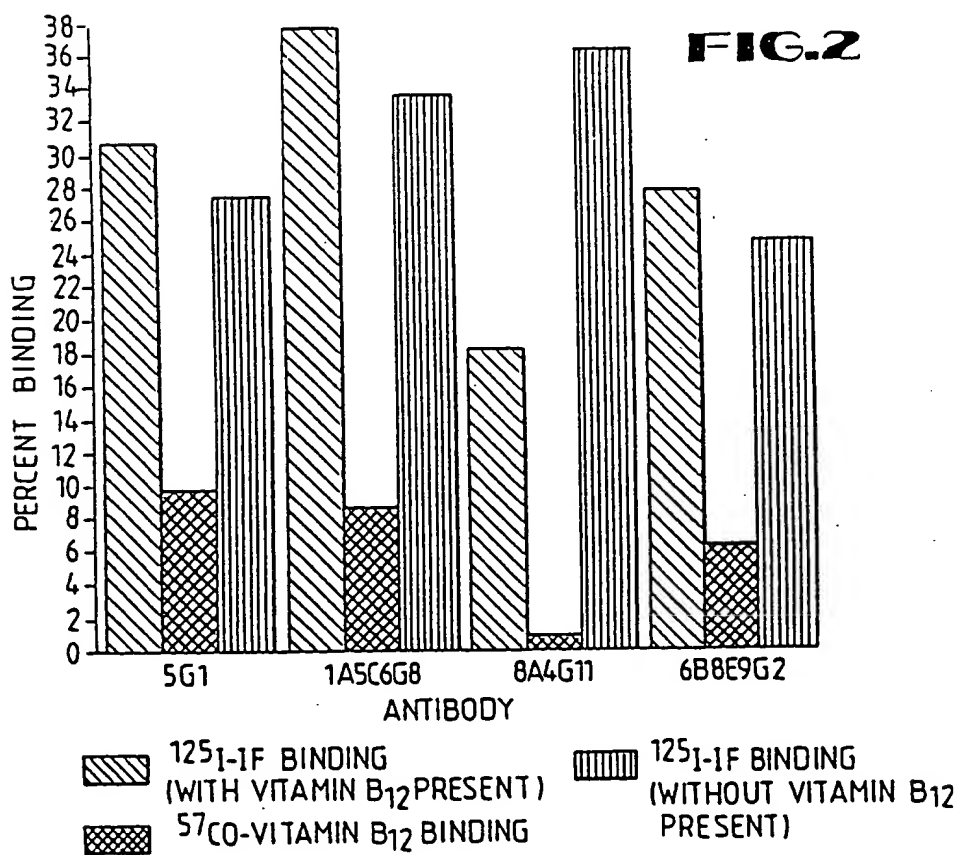
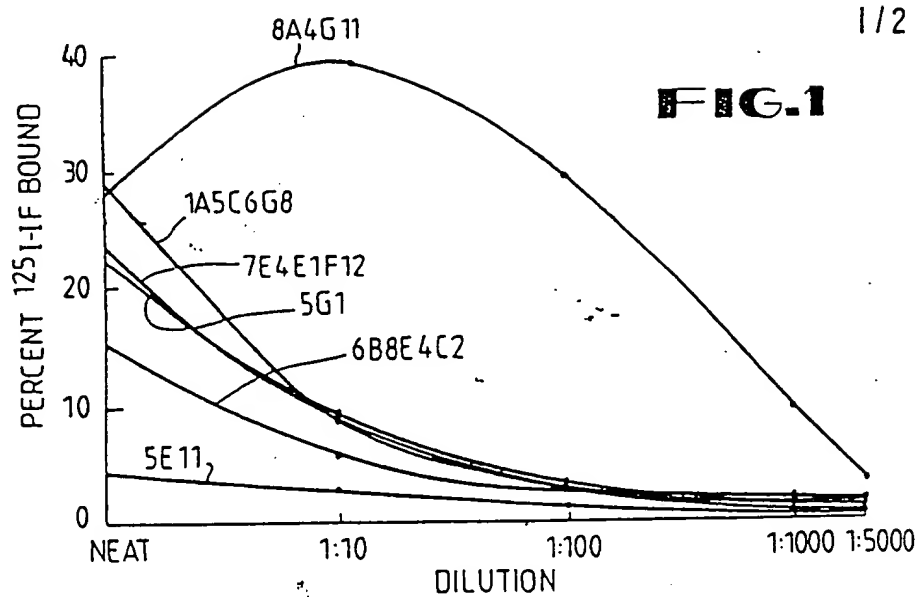
21. The process of claim 16 wherein in step (e), the  
amount of excess monoclonal antibodies is measured, said  
value being inversely proportional to the amount of  
vitamin B<sub>12</sub> present in the sample.

22. The process of claim 16 wherein step (c) involves  
contacting said sample with antibodies specific to the  
label used for the monoclonal antibodies of step (b),  
coupled with magnetizable particles, to form a complex  
with the intrinsic factor: vitamin B<sub>12</sub>: antibody complex,

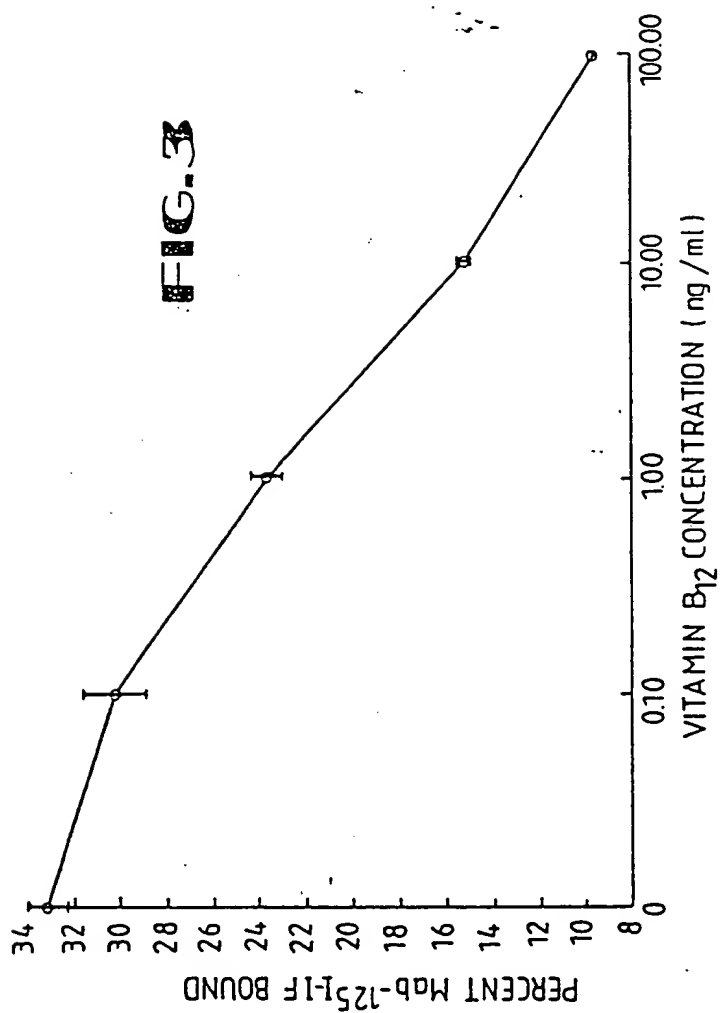
- 24 -

and the separation step (d) is by magnetic particle separation.

1/2

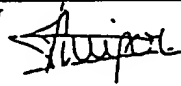


2/2



## INTERNATIONAL SEARCH REPORT

International Application No PCT/US 90/03416

|   |   |                                     |
|---|---|-------------------------------------|
| I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) <sup>6</sup>  |   |                                     |
| According to International Patent Classification (IPC) or to both National Classification and IPC   |   |                                     |
| IPC5: G 01 N 33/53, 33/577, 33/82, C 07 K 15/28   |   |                                     |
| II. FIELDS SEARCHED   |   |                                     |
| Minimum Documentation Searched <sup>7</sup>   |   |                                     |
| Classification System   | Classification Symbols  |                                     |
| IPC5  | G 01 N; C 07 K  |                                     |
| Documentation Searched other than Minimum Documentation to the extent that such Documents are Included in Fields Searched <sup>8</sup>  |   |                                     |
| III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>   |   |                                     |
| Category <sup>10</sup>  | Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>  | Relevant to Claim No. <sup>13</sup> |
| A   | US, A, 4447528 (JAMES E. ELLIS ET AL.)<br>8 May 1984,<br>see the whole document<br>--   | 1-11                                |
| A   | Chemical Abstracts, volume 69, no. 21, 18 November 1968, (Columbus, Ohio, US), Samloff I. et al.: "Rabbit blocking and binding antibodies to human intrinsic factor and intrinsic factor-B12 complex", see page 794, abstract 85058x, & J. Immunol. 1968, 101( 3), 578- 586<br>-- | 2,3                                 |
| A   | US, A, 3981863 (GORDON DEAN NISWENDER ET AL.)<br>21 September 1976,<br>see the whole document<br>--   | 1,12                                |
| <p><sup>10</sup> Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p> |   |                                     |
| IV. CERTIFICATION   |   |                                     |
| Date of the Actual Completion of the International Search   | Date of Mailing of this International Search Report   |                                     |
| 15th October 1990   | 29 OCT 1990   |                                     |
| International Searching Authority   | Signature of Authorized Officer   |                                     |
| EUROPEAN PATENT OFFICE  | Mme N. KUIPER   |                                     |

| III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET) |  |                      |
|--|--|----------------------|
| Category   | Citation of Document, with indication, where appropriate, of the relevant passages   | Relevant to Claim No |
| Y  | Chemical Abstracts, volume 82, no. 1, 6 January 1975, (Columbus, Ohio, US), Van de Wiel, D.F.M. et al.: "Production and purification of antibody against protein-vitamin B12 conjugates for radioimmunoassay purposes ", see page 167, abstract 1801s, & Clin. Chim. Acta 1974, 56(2), 143- 149<br>--  | 12-22                |
| Y  | EP, A2, 0238353 (SERONO DIAGNOSTICS PARTNERS (A MASSACHUSETTS LIMITED PARTNERSHIP))<br>23 September 1987,<br>see fig. 2, page 1 and page 4, lines 37-63<br>--  | 12-22                |
| A  | National Library of Medicinedatabase, Medline, File Med 77, NLM Accession no. 77258759, O'Brien HA et al: "A radioisotope dilution assay for unlabelled vitamin B12-intrinsic factor complex employing the binding intrinsic factor antibody; probable evidence for two types of binding antibody", & Scand J Haematol 1977 Aug; 19(2):201-6<br>-- | 12-22                |
| A  | Chemical Abstracts, volume 101, no. 7, 13 August 1984, (Columbus, Ohio, US), Shepherd H.A. et al.: "The preparation of human intrinsic factor-cobalamin complex from human gastric juice by immunoabsorption ", see page 280, abstract 50981v, & Clin. Chim. Acta 1984, 139(2), 155- 165<br>--   | 13                   |
| A  | WO, A1, 8806632 (ADVANCED MAGNETICS, INC.)<br>7 September 1988,<br>see pages 44-47<br>--<br>-----  | 22                   |

This annex is  
The members  
The European

|        |       |
|--------|-------|
| P      | cites |
| US-A-  | 4     |
| US-A-  | 3     |
| EP-A2- | 0     |
| WO-A1- | 8     |

For more detail

EPO FORM P04

ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO. PCT/US 90/03416

SA 38305

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
The members are as contained in the European Patent Office EDP file on 27/09/90  
The European Patent office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|---|---------------------|----------------------------|---------------------|
| US-A- 4447528                             | 08/05/84            | FR-A-B- 2511155            | 11/02/83            |
|   |                     | GB-A-B- 2104216            | 02/03/83            |
|   |                     | JP-A- 58038862             | 07/03/83            |
| US-A- 3981863                             | 21/09/76            | US-A- 4082738              | 04/04/78            |
| EP-A2- 0238353                            | 23/09/87            | JP-A- 62284262             | 10/12/87            |
| WO-A1- 8806632                            | 07/09/88            | CA-A- 1254028              | 16/05/89            |
|   |                     | CA-C- 1266769              | 20/03/90            |
|   |                     | EP-A- 0125995              | 21/11/84            |
|   |                     | EP-A- 0357593              | 14/03/90            |
|   |                     | JP-A- 60001564             | 07/01/85            |
|   |                     | US-A- 4554088              | 19/11/85            |
|   |                     | US-A- 4628037              | 09/12/86            |
|   |                     | US-A- 4672040              | 09/06/87            |
|   |                     | US-A- 4695392              | 22/09/87            |
|   |                     | US-A- 4695393              | 22/09/87            |
|   |                     | US-A- 4698302              | 06/10/87            |

For more details about this annex : see Official Journal of the European patent Office, No. 12/82